

## HOLOCENE SEISMIC AND TECTONIC ACTIVITY IN THE DEAD SEA AREA

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### ABSTRACT

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The Dead Sea is a large, active graben within the Dead Sea rift, which is bounded by two major strike-slip faults, the Jericho and the Arava faults. We investigated the young tectonic activity along the Jericho fault by excavating trenches, up to 3.5 m deep, across its trace. The trenches penetrate through Late Pleistocene and Holocene sediments. We found that a zone, up to 15 m wide, of disturbed sediments exists along the fault. These disturbed sediments provide evidence for two periods of intensive activity or more likely, for two major earthquakes, that occurred during the last 2000 years. The earthquakes are evident in small faults, vertical throw of a few layers, cracks, unconformities and wide fissures. We further documented evidence for recent sinistral shear along the Jericho fault in deformed sediments and damage to an 8th Century palace on a subsidiary fault. We suggest that the two earthquakes may be correlated with the 31 B.C. earthquake and the 748 A.D. earthquake, reported by the ancients.

### INTRODUCTION

The Dead Sea rift forms part of the boundary between the Arabian and African-Sinai plates (Fig. 1). The region has been populated for thousands of years and there exist records of seismic events which have occurred during the last 3000 or so years (e.g. Shalem, 1956; Poirier et al., 1980; Ben-Menahem, 1981). The nature of these historical records ranges from poetic descriptions of the destruction of places such as Sodom and Gomorrah or the walls of Jericho that may be related to seismic events, to specific reports of actual earthquakes (detailed list in Ben-Menahem, 1981). A few of these events have been verified by still recognizable damage to archaeological

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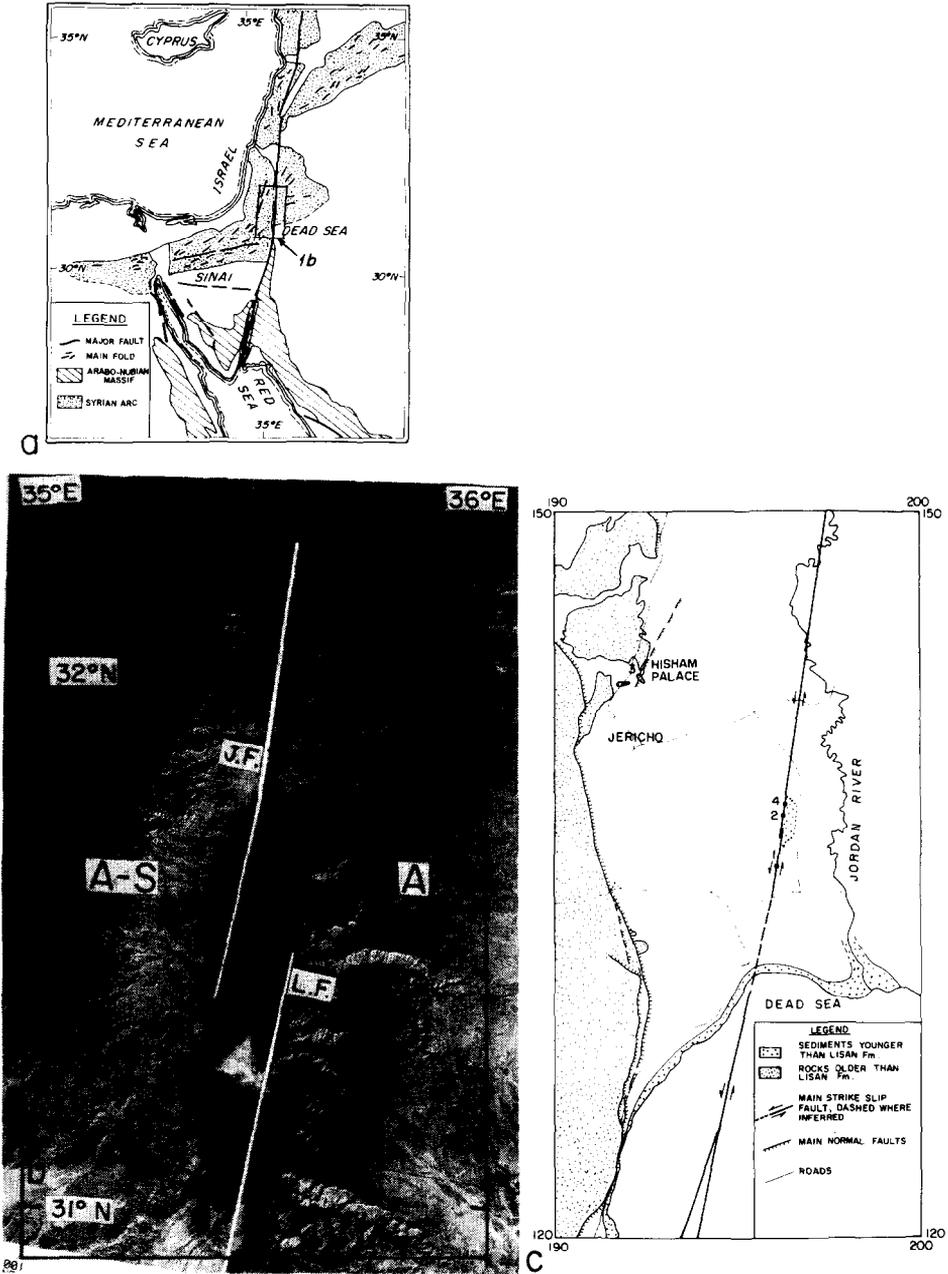


Fig. 1. a. Regional tectonic map of the Dead Sea rift. b. Main faults and plates motion in the Dead Sea area. Area of figure is marked on Fig. 1a. A = Arabian plate; A-S = African-Sinai plate; J.F. = Jericho fault; L.F. = Arava fault. Heavy arrows indicate relative plate motion. c. Site location of the present study. Area of figure is marked on Fig. 1b. Grid numbers refer to Israel Grid (in km).

remains (e.g. Karcz and Kafri, 1978). In this paper we present information on seismic activity during the last 2000 years in the area of the Dead Sea, based on detailed investigations of the deformation of Late Pleistocene and Holocene sediments, as well as the damage of an 8th Century palace.

*Tectonic movement along the rift* is predominantly sinistral horizontal shear with minor extension (Fig. 1). The Dead Sea rift forms an elongated depression, approximately 1000 km long, which is bounded by normal faults and flexures on its margins. Strike-slip faults are arranged en echelon in the central portion of the depression (see Garfunkel, 1981). These faults are rotated in a clockwise sense with respect to the trend of the Dead Sea rift, and bound rhomb-shaped grabens (e.g. Freund and Garfunkel, 1976). The Dead Sea occupies the largest, most active rhomb-shaped graben along the rift system. It is bounded by the Arava fault on the east and the Jericho fault on the west (Neev and Hall, 1978; Garfunkel, 1981). The Holocene deformation in the Dead Sea region is concentrated along these strike-slip faults according to instrumental and geological data (e.g. Ben-Menahem et al., 1976; Neev and Hall, 1978; Garfunkel, 1981).

*The Jericho fault* is the main subject of the present investigation. It trends for about 30 km in a N10°E direction along the west coast of the Dead Sea and then for about 50 km or more on land, north of the sea (Fig. 1). The Jericho fault is predominantly a strike-slip fault; however, locally there are extensional to compressional components. The southern segment of the fault, beneath the Dead Sea water (Fig. 1c), has a normal component (Neev and Hall, 1978). A few kilometers north of the Dead Sea (location 1, Fig. 1c), however, the Jericho fault is essentially a strike-slip fault (see below). At location 2, only 1½ km north of location 1, the fault again has an extensional component and a small depression is developed along the fault. Further to the north, along the same fault, an anticline is developed in the Lisan Formation (Garfunkel, pers. commun., 1980). This alternation of the local displacement, typical of strike-slip faults, is discussed by Garfunkel (this volume).

*Holocene tectonic activity* is generally recognised by prominent fault scarps, offset morphological features, such as alluvial fans, and tectonically related vegetation patterns (e.g. Zak and Freund, 1966; Wallace, 1978; Sieh, 1978a; Garfunkel et al., 1981). Another means of documenting such tectonic activity is by investigating ground deformation and surface rupture preserved in young sediments which are deposited over an active fault zone (e.g. Clark et al., 1973; Sieh, 1978b). The method of obtaining such information is by excavating a trench across the fault zone and studying the stratigraphy and structure of the deformed sediments. For example, Sieh (1978b) determined the recurrence time of large historic earthquakes along the San Andreas fault by studying the ground deformation at Pallett Creek, California. The fast rate of deposition, distinct bedding and good preservation of organic material for <sup>14</sup>C dating, makes the Pallett Creek site an almost ideal site for such study.

The Dead Sea region, in this respect, is not an ideal location for documenting historic ground deformation. Problems arise due to the rapid destruction of surface features by erosion, the low productivity of the area leads to only small amounts of organic material being preserved and coarse clastic deposits do not produce a detailed stratigraphic record. On the other hand, the occurrence of recognizable pottery fragments in the sediments, the existence of deformed ancient structures, the relatively slow slip rate (about 7 mm/year) and the availability of historic records, more than offset the disadvantages.

#### DISTURBED SEDIMENTS ALONG THE JERICHO FAULT

##### *Methods*

We excavated nine trenches across the Jericho fault in the area east of the Dir Hagla Monastery (Fig. 1c). The three southern trenches, numbered 1, 2 and 7, exposed Lisan and recent stream sediments (location 1 in Fig. 1c). The five central trenches, numbered 3, 4, 5, 6 and 8, are on the margins of the small depression, or graben, which is bounded on the west by the Jericho fault (location 2 in Fig. 1c). There is no clear fault bounding the depression on the east. In all five central trenches, we found sediments younger than 2500 years unconformably overlying the Lisan Formation or faulted against the Lisan sediments. In a group of three trenches (numbers 3, 5, 6, Fig. 2) which are located close to a spring, we found the best evidence of seismic events. The northern trench (number 9, location 4 in Fig. 1) exposes sediments of a present day stream, Wadi el-Qilt, which overlies the Lisan Formation and are displaced by a 0.8 m normal fault.

The trenches were excavated to a depth of up to 3.5 m by a backhoe tractor. The longest trench is 40 m long. All trenches were carefully examined and three were mapped in detail. The walls of the trenches were mapped on a scale of either 1:10 or 1:20 by tracing the exposed sediments as seen through a net with 10 × 10 cm holes. The walls of the trenches remained stable for at least 1 year, even when unsupported. The groundwater table is 6–8 m below the surface west of the Jericho fault in location 2 (Fig. 1c). The faults act here as a barrier for groundwater. Two trenches in location 1, Fig. 1, which were cut into stream beds, were destroyed in the first major flood of winter 1979.

A vertical coordinate system of 1 × 1 m was established in the trenches. Trenches in the same vicinity, such as 1 and 2 (Fig. 3) and the group of 3, 5 and 6 (Fig. 2), are parallel and have the same local coordinate system. There is no relationship of the location of the coordinate origin between distantly located groups of trenches. To locate a point in a given profile of a trench, we use three digits which relate that point to an arbitrary coordinate origin. For example, 3-14/12 corresponds to the point marked A in Fig. 7. The first digit indicates the trench number, the second digit the vertical coordinate in meters, to the right of the point, and the third digit is the horizon-

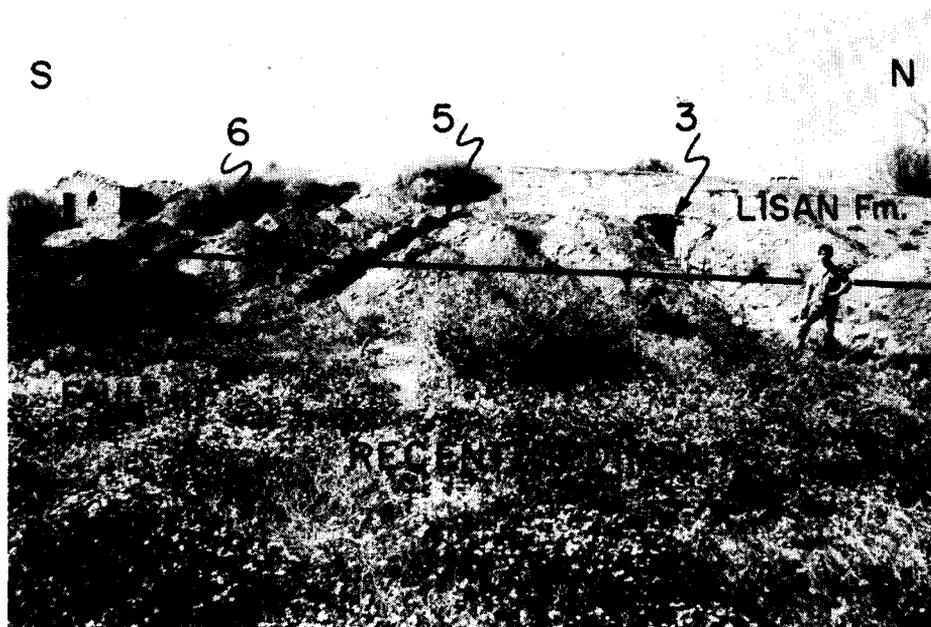


Fig. 2. The site of the central trenches, on the margins of the Dir Hagla depression (location 2, Fig. 1c). The numbers refer to three parallel trenches excavated across the trace of the main fault.

tal coordinate in meters, below the point. A location 3-145/121 gives the coordinates in decimeters, and thus provides a more precise location.

The profiles of the southern walls of the three trenches are shown in Figs. 5–8. The local coordinate systems are marked at the margins.

*Stratigraphy.* The Jericho fault cuts across sediments of the Lisan Formation as well as younger deposits (Fig. 1c). The sediments which were found

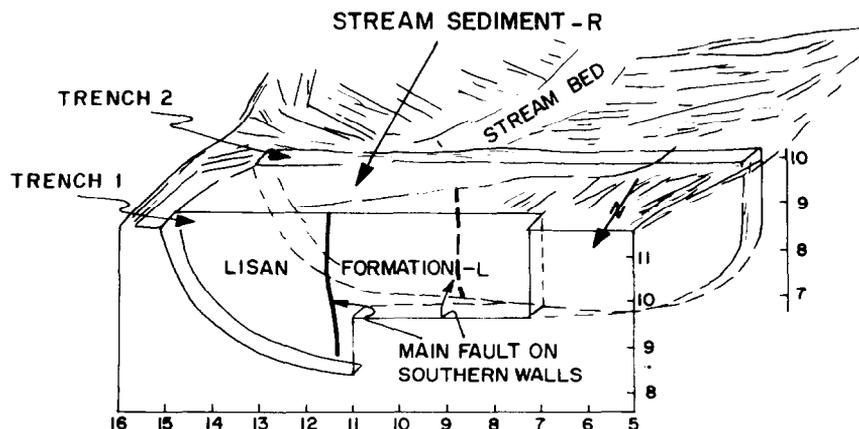


Fig. 3. The southern trenches across the Jericho fault (location 1, Fig. 1c). Numbers on the frame indicate the local coordinate system, in meters, of these two trenches.

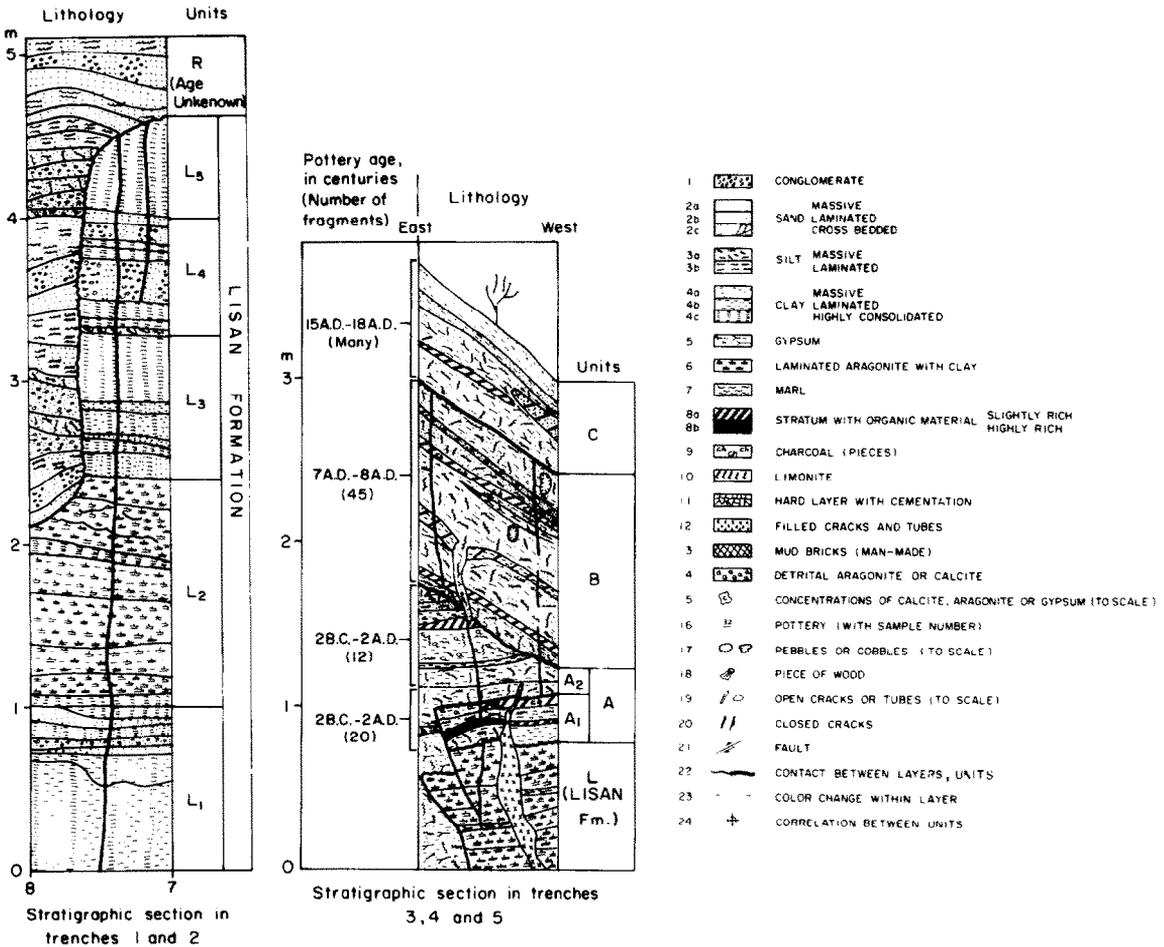


Fig. 4. Stratigraphic sections of the southern trenches (1 and 2) and the central trenches (3, 4, 5 and 6).

in the trenches are shown in the stratigraphic sections of Fig. 4. The Lisan sediments include layers of clay up to 0.5 m thick, aragonite finely laminated with clay, and a few layers of sand and conglomerate (Figs. 4–6). The younger sediments, formed during the last few thousands years, were deposited as a prism on a fault scarp surface, over the Lisan sediments (Figs. 4, 7, 8). They are primarily clastic, mostly clay, silt and fine sand, which are deposited as slightly irregular layers. Local unconformities, cut-and-fill structures and onlapping structures are common. Several dark layers in the sequence, contain organic material and the remains of past fires. Small fragments of charcoal, bones and pottery occur in many layers. Some layers are partly cemented by secondary gypsum or calcite. Cementation boundaries correlate with bedding contacts. Several thin layers are composed of finely laminated

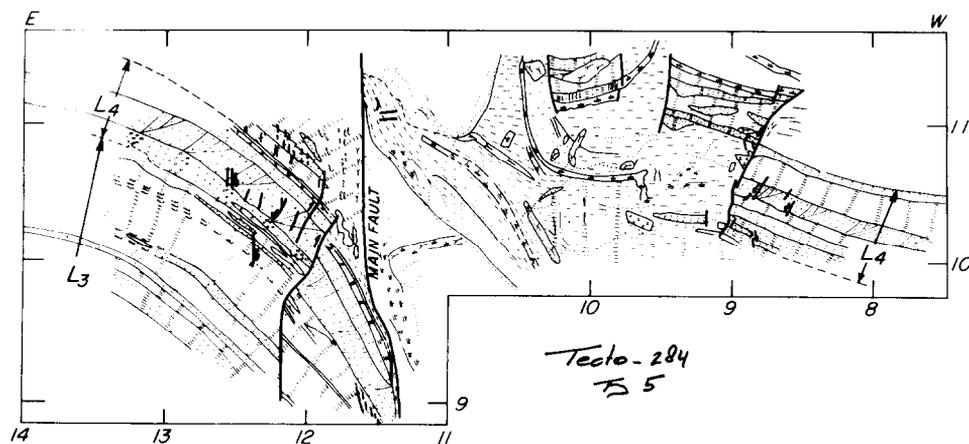


Fig. 5. Section of the southern wall of trench 1 (location 1, Fig. 1). The trench trends to  $115^{\circ}$ . Field mapping at scale of 1 : 10. Legend in Fig. 4 and relationship to trench 2 in Fig. 3. All sediments are of the Lisan Formation (Fig. 4). The flexed layers dip to the northwest. Horizontal slickensides were found on the main fault. Note the layer with cross-bedding, unit  $L_4$  (Fig. 4) in both sides of the fault.

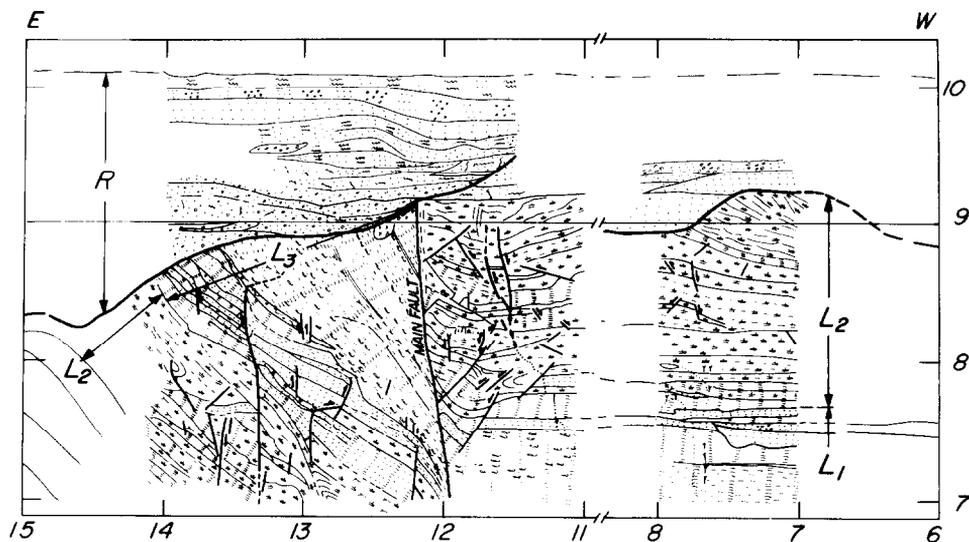


Fig. 6. Section of the southern wall of trench 2, 9 m south of trench 1 (Fig. 3). The trench trends to  $115^{\circ}$ . Field mapping at scale of 1 : 10. Legend in Fig. 4 and relationship to trench 1 in Fig. 3. The section was shortened between coordinates 8.0 and 11.0 where bedding was continuous and horizontal. The lower part of the sequence is of Lisan Formation which is overlain unconformably by recent stream sediments (Fig. 4).

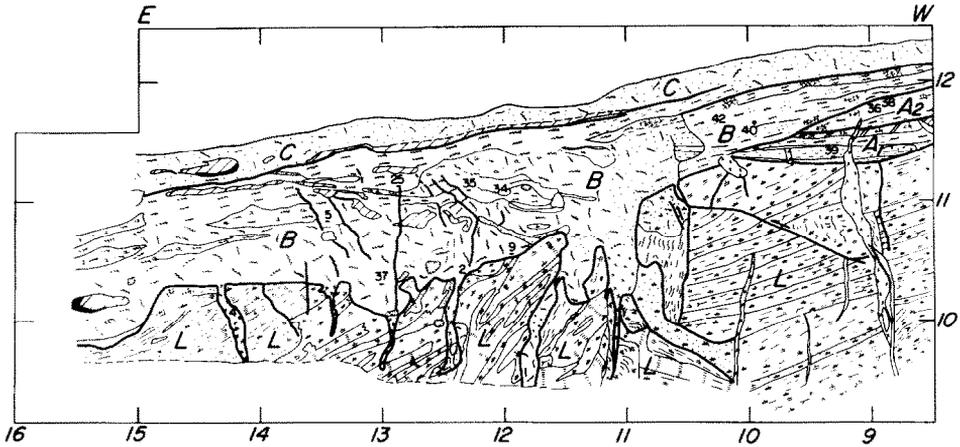


Fig. 7. Section of the western part of the southern wall of trench 3 (location 2, Fig. 1c and Fig. 2). The eastern continuation of this section is shown in Fig. 8. The trench in E—W direction. Field mapping at scale of 1 : 10. Legend in Fig. 4.

clay which was deposited in undisturbed water bodies. Some layers contain concentrations of the shells of a snail, *Melanopsis* (sp.), indicating a local fresh-water source. No residual soil horizons have been recognized in the sequence. Layers are continuous laterally for up to a few meters, and only a few thin layers can be correlated between adjacent trenches. We have correlated *groups* of layers, units L, A<sub>1</sub>, A<sub>2</sub>, B, C and R according to lithological similarity (Fig. 4). Several of these units are bounded by unconformities. For example, top of unit L, base of units A<sub>1</sub>, A<sub>2</sub>, B and R (Figs. 4—8). In trenches 5 and 6 we found man-made structures which were built on and into the young sediments.

In summary, the stratigraphic sequence found in trenches 3, 4, 5 and 6 (Figs. 4, 7, 8) indicates subaerial clastic sedimentation of clay to sand grain size with minor amounts of subaqueous deposits. The pebbles and boulders in the sequence, were probably brought by man. The source area for sediments is local and transport is by wind and local runoff.

*Dating of the recent sediments* in the present study is based on preserved fragments of pottery. Attempts at carbon-14 dating have not been successful due to the small amounts of organic material available and possible contamination by modern organic material. The age of the pottery fragments was established on the basis of their ornamentation and production style by Mr. Y. Porat, Department of Antiquities, Israel. Some of the pottery fragments are marked on the profiles of the trenches (Figs. 4, 7, 8). We found, in situ, about 150 pottery fragments, ranging in age from modern to 3500 years. Many of them are not indicative of a specific period. Only the youn-

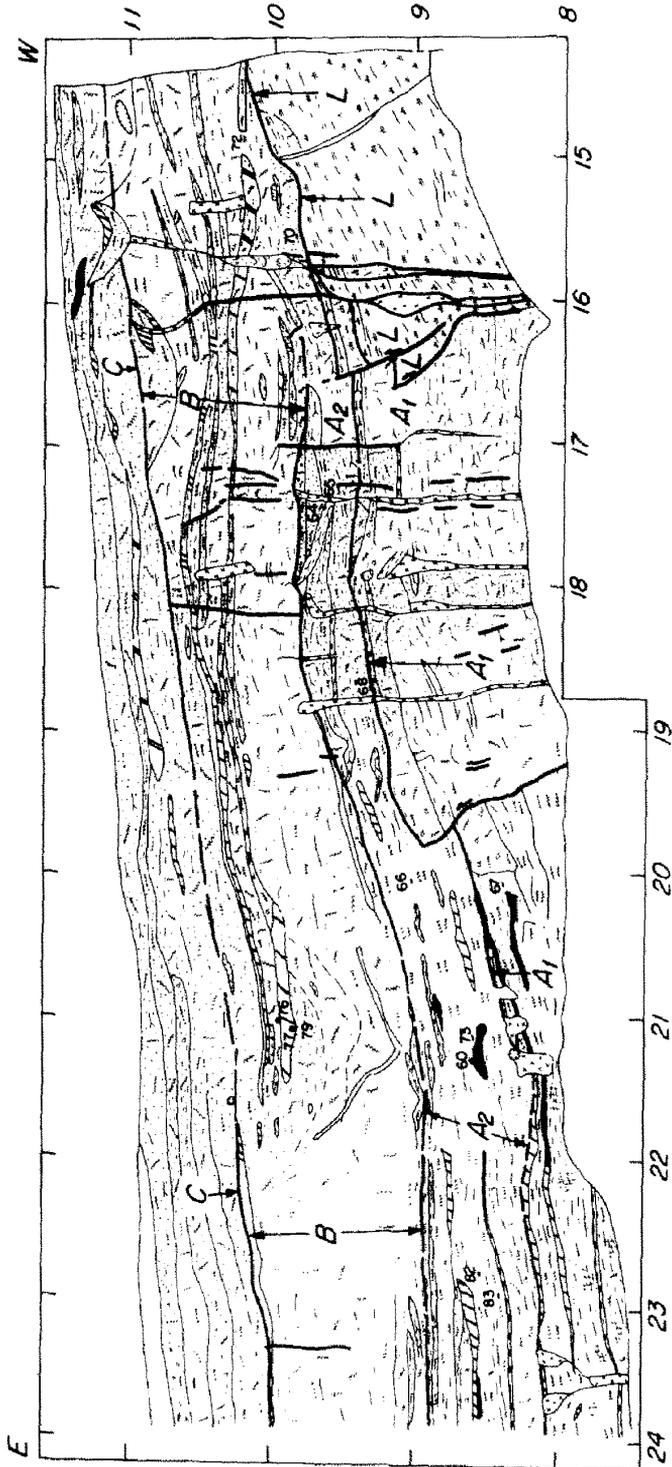


Fig. 8. Section of the eastern part of the southern wall of trench 3 (location 2, Fig. 1c and Fig. 2). The western continuation of this section is shown in Fig. 7. The trench in E-W direction. Field mapping at scale of 1 : 20. Legend in Fig. 4.

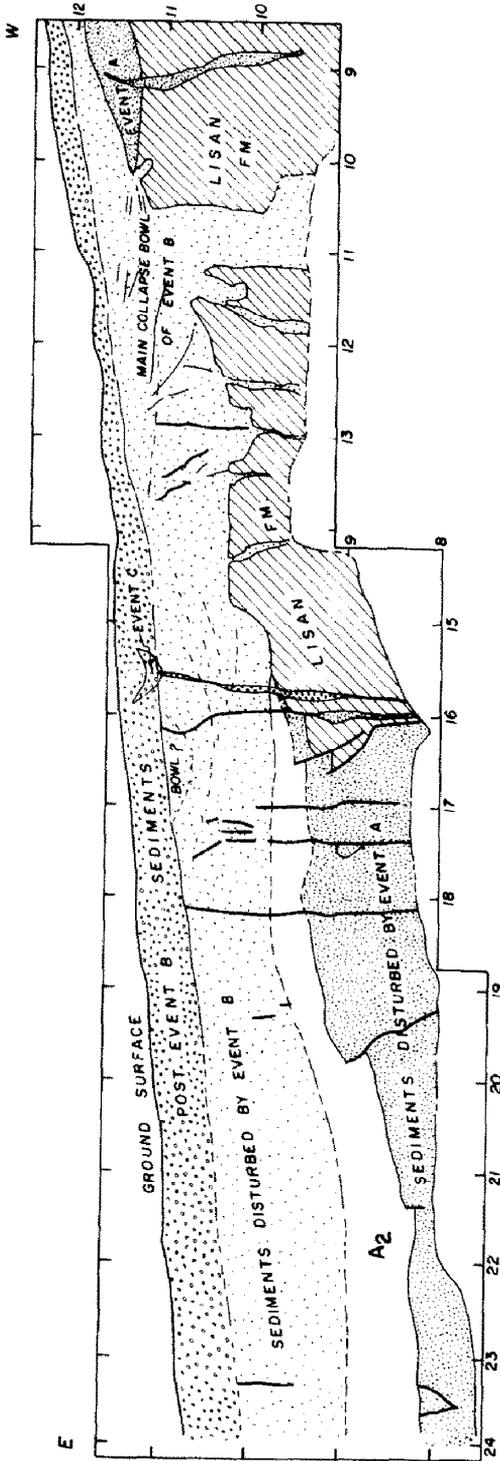


Fig. 9. Generalized sections of the main fault zone in trench 3, with the structures that formed during past earthquakes. Two major events can be distinguished. For more details, compare with Figs. 7 and 8.

gest fragments found in a layer can, of course, be used for age determination. We therefore could date only groups of layers, rather than individual ones (Fig. 4).

*The earthquakes and the displacements* along the Jericho fault generated a 10–15 m wide zone of intensive deformation. The deformation features may be related to seismic events, if they form during the event, or during a period of few years following the event. On the other hand, some features may be attributed to geotechnical, groundwater or human causes which are not directly related to seismic events. The distinction between the seismic and nonseismic features is sometimes difficult. Presented below are the features which, according to our interpretation, are most likely of seismic cause. This is based on sense of motion, location and the nature of development of these features, and their similarity to features observed across other active faults.

## *Results*

We identified two “events” which occurred along the Jericho fault during the last 2000 years. These events, referred to as event A and event B, can be recognized in trenches 3, 4 and 5. Each event represent intensive seismic activity; however, due to the coarse lamination, it is impossible to ascertain if each one represents a single large earthquake or multiple earthquakes during a short period. In this study, we suggest that these events represent individual earthquakes and correlated them with historic records.

We have also found evidence for considerable slip along the Jericho fault in trenches 1 and 2. We will first describe the evidence for the two earthquakes, and will then present the information relating to the slip along the fault.

### *Event A*

The older event is evident in unit  $A_1$  and, in part, in unit  $A_2$  as seen in the central trenches 3, 4 and 5 (Figs. 4, 9). Several small faults, wide fissures, filled cracks, significant vertical throw and large unconformities are thought to have resulted from this earthquake. The following is a detailed description of these phenomena.

*Small faults*, with displacements of up to a few tens of cm, cut through unit  $A_1$  (Fig. 4) in both trench 3 (Figs. 7, 8), and trench 5. These are faults with either reverse- or normal-separation, with either the east or west side downthrown. The fault surfaces are usually irregular, with no slickensides. The faults are truncated by unit  $A_2$  in locations 3-164/096 and 3-198/090 (Figs. 8, 10). *Wide fissures*, bounded by small faults and filled with either layered (Fig. 10) or mixed sediments (3-091/115 in Fig. 7 and 3-213/083 in Fig. 8) cut through unit  $A_1$ . Stratified layers of unit  $A_1$  are preserved in the fissures of trench 5, whereas this unit was eroded from both sides of the

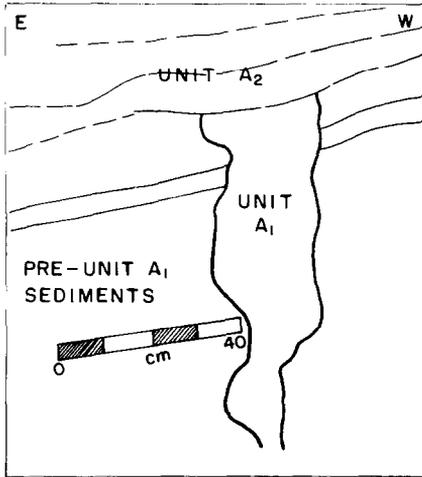


Fig. 10. A wide fissure, bounded by two small faults, in trench 5. A sequence of unit  $A_1$  (Fig. 4) is preserved within the fissures but is eroded from both sides of it (drawn after a photograph).

fissure (Fig. 10, and compare with fig. 18, Sieh, 1978b). A few *filled cracks* and pockets of mixed sediments occur within unit  $A_1$ . For example, a vertical one meter long crack at location 3-178/090, an irregular crack at 3-235/077 or a small pocket at 3-210/084 (Fig. 8). Unlike the fissures described above, there is no displacement across the cracks and pockets.

A *vertical separation* of about 3.5 m is evident between the subhorizontal layers of unit  $A_1$  at 3-090/115 (Figs. 7, 9), and the same layers at 3-220/085 (Figs. 8, 9). This vertical separation poses several questions. Does it represent the throw during event A or an accumulative subsidence during the last 2000 years, or does this separation reflect the initial deposition of unit  $A_1$  on an inclined surface? The horizontality of unit  $A_1$  layers on both sides of the disturbed zone (Fig. 9), the continuity of the layers and their lithological consistency in trenches 3 and 5 indicate that this unit was deposited on a relatively stable, horizontal surface. Units B and C (Fig. 4) on the other hand, have a distinctive eastward thickening and inclination (Figs. 7, 8). We thus conclude that the 3.5 m vertical separation is not depositional, but rather the local tectonic throw. This vertical separation occurred during event A or during a period of a few hundreds years, following event A and preceding event B. At present, we prefer the first possibility, but there are no evidence to reject the second. One should note, however, that the horizontal slip along the Jericho fault, associated with event A is not simply related to the local throw. The latter may be significantly increased due to variation of the fault attitude (e.g. Eyal, 1973), fault trend (e.g. Garfunkel, this volume) or the en-echelon pattern (e.g. Freund and Garfunkel, 1976).

Finally, the top of unit A is bounded by a clear *unconformity* (Figs. 4, 7, 8, 9). For example, the base of unit B is deposited on an inclined surface cutting through Lisan and unit A<sub>1</sub> layers, whereas unit A<sub>2</sub> has been completely eroded away (right upper side of Fig. 7; Fig. 9). This unconformity can also be traced in the eastern side of the main fault (note thinning of unit A<sub>2</sub> in Fig. 9). The large vertical throw, discussed above, probably produced a fault scarp at the site of the trenches. Intensive erosion, probably converted this scarp into a debris controlled slope in a relatively short period (e.g. Wallace, 1978). We think that this major unconformity at the base of unit B may represent the stage of fault scarp erosion at the time of deposition of unit B.

The *age* of unit A is determined by using an assemblage of 35 identifiable pottery fragments. The fragments range from the Iron Age to Early Roman, namely, from about the 12th century B.C. to the first century A.D. Because of reworking, the youngest fragments indicate the maximum age of this unit, which is about 1900–2000 years. The coarse stratigraphy and the relative scarcity of useful pottery fragments, prevent a more specific age determination.

Conspicuous among the historic records of seismic events during this period is a vivid description by Josephus of an earthquake in the year 31 B.C. (Josephus, "Antiquities of the Jews", Book XV, Ch. 5). He wrote: "At this time it was that the fight happened at Actium, between Octavius Caesar and Anthony in the seventh year of the reign of Herod and it was also that here was an earthquake in Judea, such a one as had not happened at any other time and this earthquake brought a great destruction upon the cattle in that country. About 10,000 men also perished by the fall of houses, but the army, which lodged in the field, received no damage by this sad accident." It is feasible, that this earthquake may be the same as "event A".

### *Event B*

Evidence for a second earthquake in the central trenches can be seen in unit B (Figs. 4, 9). This event is recognized by bowl-shaped depressions, open and closed cracks, vents, filled fissures and small faults. Some of these features are described in detail. *Bowl-shaped depressions* are characterized by oppositely facing layers or a bowl filled with disturbed sediments (Fig. 11). The bowl structures vary in width from about 20 cm (2-157/111 in Fig. 8) to almost 2.0 m (3-11/11 in Fig. 7). Most of the *cracks* in unit B are sub-vertical, with rough and irregular surfaces. A few cracks are open and their surfaces are coated with fine brown clay with flow striations. Several cracks are filled with an unsorted, non-laminated mixture of clastic material, with a few fragments of pottery (3-142/100 in Fig. 7). This mixture is loosely cemented by gypsum needles in a few places. Most of the cracks in trench 3 terminate close to the top of unit B (Fig. 9), suggesting that they developed, at the end of the deposition of this unit. *The filled fissures*, 5–10 cm wide, which are common at the base of unit B (Figs. 7, 9), are somewhat similar

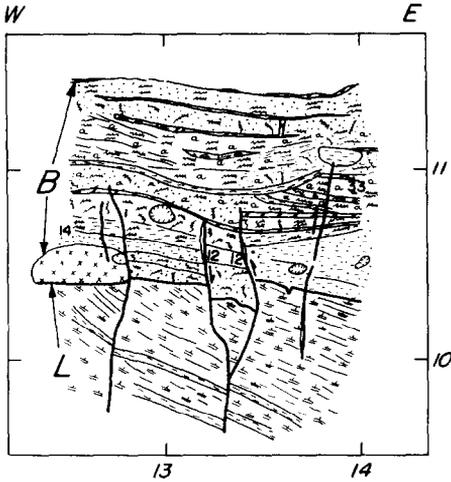


Fig. 11. A bowl-shaped depression in layers of unit B (Fig. 4) on the northern wall of trench 3 (Fig. 2). Coordinate system as in Fig. 7. The layered depression is underlain by two small faults that penetrate into the Lisan layers.

to the filled cracks, described above. These wide fissures have irregular faces, without slickensides or apparent displacement. The occurrence of mixed sediments of unit B in the fissures (e.g. 3-11/10 in Fig. 7) indicate that they formed *after* the deposition of unit B. A few *small faults* with displacement of up to 10 cm also occur in unit B (e.g. Fig. 11).

The character of event B differs significantly from that of event A. The latter has clear faults and measurable throws, whereas the first has many extensional features with no apparent throw. The  $9^\circ$  eastward inclination of the top of unit B (Fig. 9) may suggest some continuous subsidence (aseismic?). On the other hand, this inclination may also be due to the degraded fault scarp of event A, which could have existed for thousands of years (e.g. Wallace, 1978). Due to the coarse layering, it is impossible to distinguish between two possible mechanisms.

The age of unit B is determined by the presence of a distinctive group of pottery fragments, dating from the Late Byzantine to Early Arabic times, namely 7–8 centuries A.D. This is the youngest assemblage in unit B, and thus, event B has probably occurred between the 7th Century and the 8th Century.

What is the slip associated with B? Could we correlate it with a known historic record? A hint of an answer is found in the nearby Hisham Palace, a luxurious complex built during the first half of the 8th Century just north of Jericho (location 3, Fig. 1). The ruins of the palace were studied in detail by Hamilton (1959), who proposed that the palace was destroyed by an earthquake, before the completion of its construction.

We found that the walls of the Hisham Palace have been subjected to

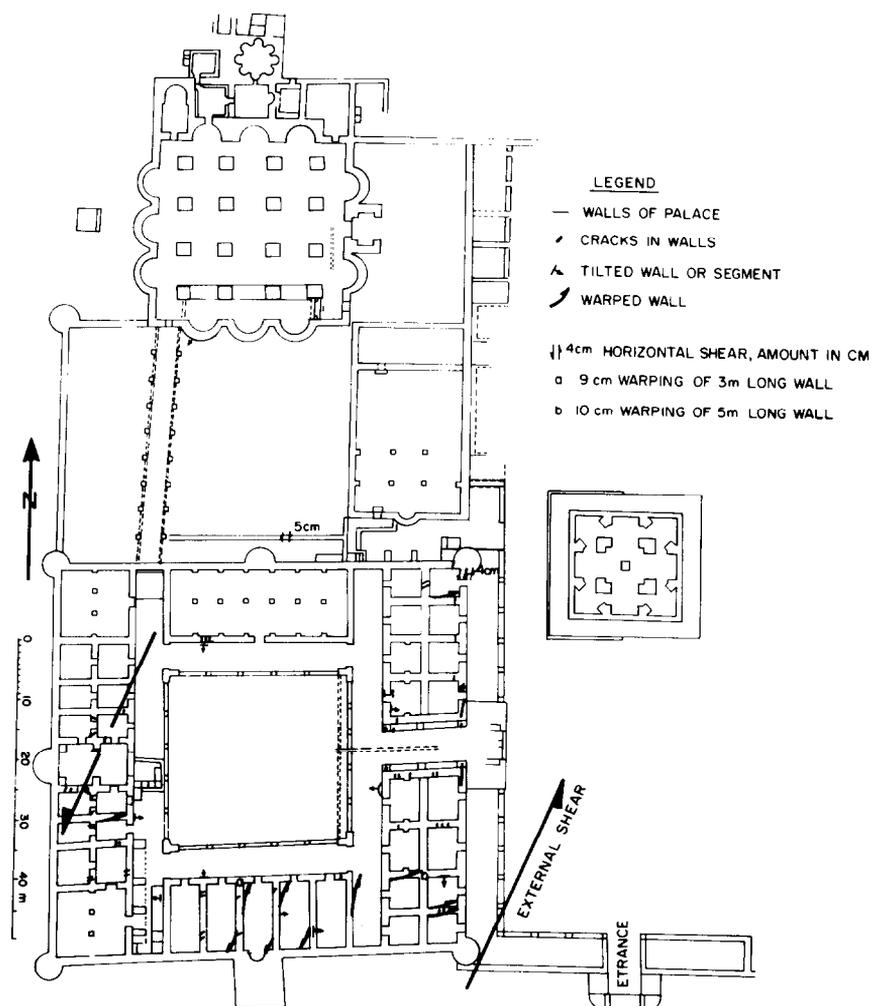


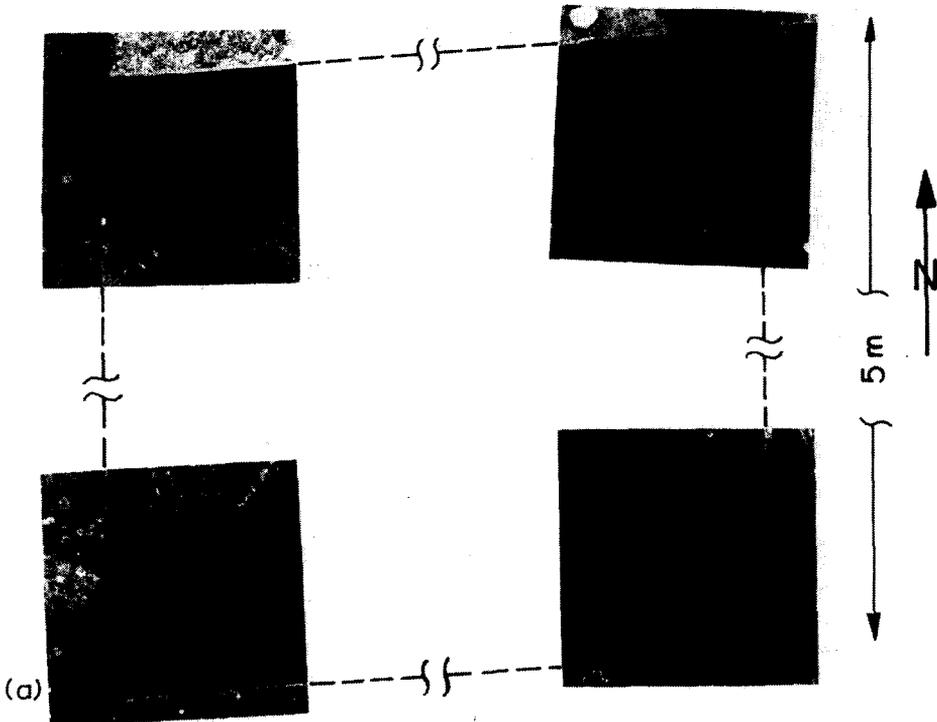
Fig. 12. Map of the Hisham Palace close to Jericho (location 3, Fig. 1c). The heavy lines indicate the main damage to the palace walls mapped in the present study. Most of the damage features are consistent with left-lateral shear parallel to the two marked solid arrows. Base map after Hamilton (1959).

severe fracturing, tilting, warping and distortion, which are consistent with sinistral horizontal shear. Figure 12 is the damage that we documented on Hamilton's map. Many rooms, particularly in the southeastern part, are rhomb-shaped (Figs. 12, 13a). The deviation of the rooms of the palace from rectangular form, was attributed by Hamilton (1958, p. 63) to errors in measuring angles during constructions. However, such errors could not explain the coherent continuous warping of many walls (Fig. 12) and the horizontal slip on several fractures (Figs. 12, 13b). As the wall warping, the slip

along fractures and shape of rooms, are all consistent with sinistral horizontal shear of the southeastern part of the palace (Fig. 12), tectonic deformation appears to be the reasonable explanation for most, if not all, damage phenomena. Begin (1975) traced an inferred fault trending  $N35^{\circ}E$ , about 100 m west of the palace. We suggest that another fault, the Hisham fault, runs with similar trend through the palace (Fig. 1c).

Ben-Menahem (1981) suggests, on the basis of historical records that the palace was destroyed by an earthquake in 748. He further suggests that this earthquake caused severe damage to hundreds of villages and death of tens of thousands of people. Ben-Menahem claims it was the strongest event in the region of Israel during the last 2500 years and attributes to it a magnitude of  $M > 7$ .

The observations of the structures in unit B, the deformation in the Hisham palace, and the historic records are all consistent with a major earthquake in 748 along the Jericho fault. The predominant displacement during this event would have been horizontal shear, which caused no considerable throw at the central trenches. The sinistral slip along the Hisham fault



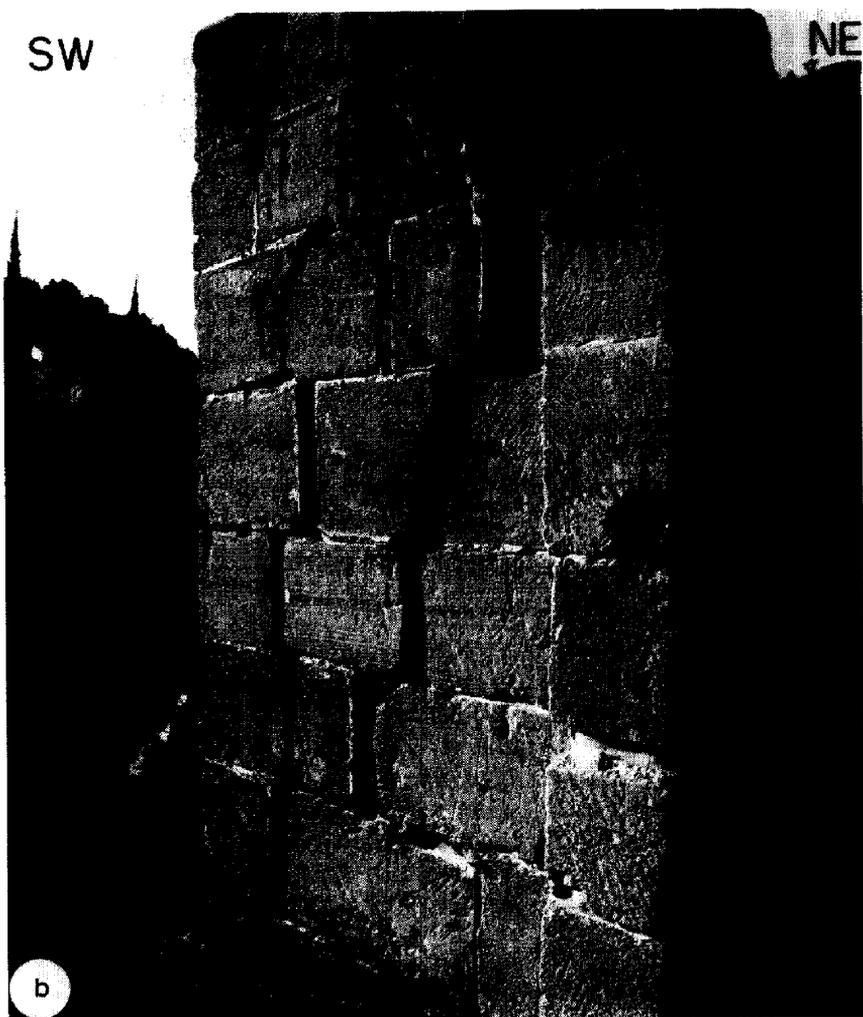


Fig. 13. a. The south eastern room of the Hisham Palace. The four corners were photographed in the field and assembled together in this figure. Note the warping at the north-western and northeastern corners. b. Sinistral horizontal offset of 4 cm in a wall in the northeastern corner of the Hisham Palace.

is probably secondary to the main 748 slip. The deformation of the palace occurred during and after the 748 event.

Evidence of young events which post-date event B is rare. The upper 0.6—1.0 m sequence is primarily disturbed by man-made structures. A possible exception is the small bowl-structure with associated cracks in 3-157/111 (Fig. 8) which formed a few hundred years ago, during a small event (event C, Fig. 9).

*Prehistoric and historic sinistral slip*

Trenches 1 and 2 (location 1 in Fig. 1c), cut through Lisan Formation and undatable stream-bed sediments. The Lisan sediments contain indications of intensive sinistral shear having occurred during the last 30,000 years (Figs. 3, 4, 5, 6). Unlike the central trenches, no indication of single events has been found in these trenches. The horizontal slip is clearly indicated by large fault surfaces, intensely flexed layers and small faults.

The dominant structure in both trenches is the main slip surface of the Jericho fault (Figs. 3, 5, 6). This surface is a smooth, semi-planar zone, trending N10° E, which is vertical in the upper part of the trench and dips steeply westward in the lower part (Figs. 5, 6). This slip surface is about 2–3 cm wide, composed of intensely sheared shale, with minor amounts of sand grains. Clear horizontal slickensides have been found on the fault surface. The Lisan layers are intensely flexed, fractures and faulted in a zone of few meters on both sides of the main slip surface (Figs. 5, 6). The flexed layers dip up to 90° to the northwest within a 2–3 m zone east of the fault (Figs. 5, 6). This flexing is formed by superposition of shear along the fault, as well as subhorizontal compression (e.g. Johnson, 1970, Ch. 3). The existence of such local compressive component is supported by the observation that the main fault is essentially a reverse fault in the lower part of the trenches (1-114/090 in Fig. 5 and 2-120/072 in Fig. 6).

Unit  $L_4$  on the east side of the fault, is at approximately the same level as the same unit on the west side of the fault (Fig. 5). This negligible vertical separation across the main fault, the narrow flexing zone and the horizontal slickensides, all indicate sinistral slip of unknown amount along this surface. However, the well developed fault zone, with distinctive slip surface suggests slip of the order of at least few tens of meters (Aydin, 1977).

## SUMMARY AND CONCLUSIONS

Two large faults are active in the Dead Sea area, the Arava fault which bounds the sea on the east, and the Jericho fault on the west. We investigated in detail the land exposures of the latter in a 6 km segment. The Jericho fault is primarily a strike slip fault, with alternation of extensional and compressional components along its length. The seismic activity during the Holocene on the west side of the Dead Sea rift, in the Jericho region, has been concentrated along this fault.

We have found that the sediments which were deposited across the Jericho fault were disturbed by two large earthquakes or two periods of earthquakes during the last 2000 years. We found also evidence of a few intermediate seismic events. However, due to coarse sedimentation, and dating difficulties, it is impossible to determine the ages of the intermediate events. The first large event occurred between 200 B.C. and 200 A.D., and the second large one occurred between 700 A.D. and 900 A.D. The first event has a vertical

throw of about 3.5 m at the trenches. The second event has a negligible vertical throw there, but it is probably associated with horizontal slip. The two seismic events have reasonable correlations with two historic events: The 31 B.C. and the 748 A.D. earthquakes. It is possible that only large earthquakes, during which the entire Jericho fault slipped, can be observed in the young sediments.

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